Voyager Bulletin

MISSION STATUS REPORT NO. 66 SEPTEMBER 23, 1981

Update

A trajectory correction maneuver on September 29 will refine Voyager 2's flight path to Uranus and target for an aimpoint to Neptune. The spacecraft's attitude control thrusters will burn hydrazine fuel for several hours to change the flight path. Several more trajectory corrections will be necessary before Voyager 2 flies past Uranus in January 1986.

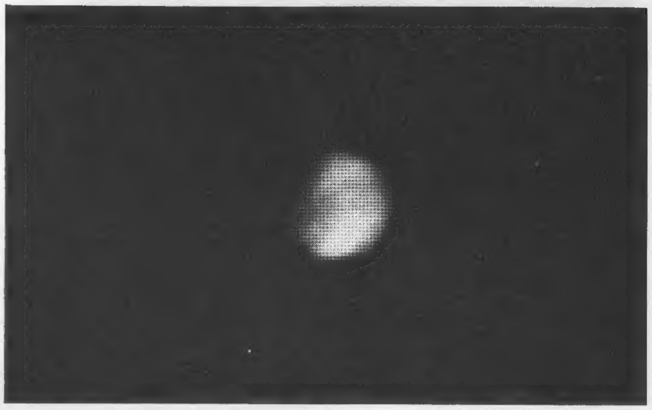
Spacecraft activities affecting the scan platform will be severely curtailed for several months as analysis continues on the problem that affects platform motion in azimuth (side to side). Motion in elevation (up and down) is unrestricted. The platform will be operated only at low rates of speed and over a limited range from 180 to 270 degrees azimuth. This range gives a satisfactory set of positions for Saturn and Uranus observations. The problem that caused the platform to stick during the spacecraft's closest approach to Saturn is believed to be a physical problem related to such things as lubrication, worn gear mechanisms, and close clearances between the gears that operate the platform. Analysis and laboratory testing with a duplicate scan platform actuator will continue efforts to isolate the cause of the problem and to determine the best strategies for future use of the platform. Instruments aboard the platform include the wide- and narrow-angle cameras, the infrared interferometer spectrometer, the ultraviolet spectrometer, and the photopolarimeter.

Saturn Science Results

The Planet

Saturn has undergone several changes in the nine months between the two Voyager flybys. These atmospheric changes are subtle, however, and shorter-lived than at Jupiter, due both to the high wind velocities which tear apart storms and to the colder temperatures which cause color-producing particles to precipitate at lower levels in the atmosphere. Although Saturn's atmosphere appears much blander than Jupiter's, many of the same fierce weather patterns rage in its clouds.

Voyager 2 saw more detail in Saturn's atmosphere for several reasons. Portions of the haze which appeared to shroud the planet nine months ago when Voyager 1 flew by have lifted. Voyager 2's imaging cameras have slightly better vidicon tubes, resulting in improved picture resolution. And, based on Voyager 1's observations, Voyager 2 could be much more selective and precise about where it looked.

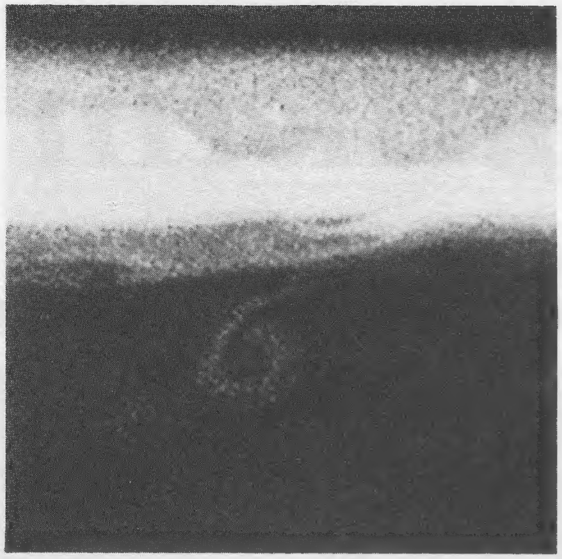


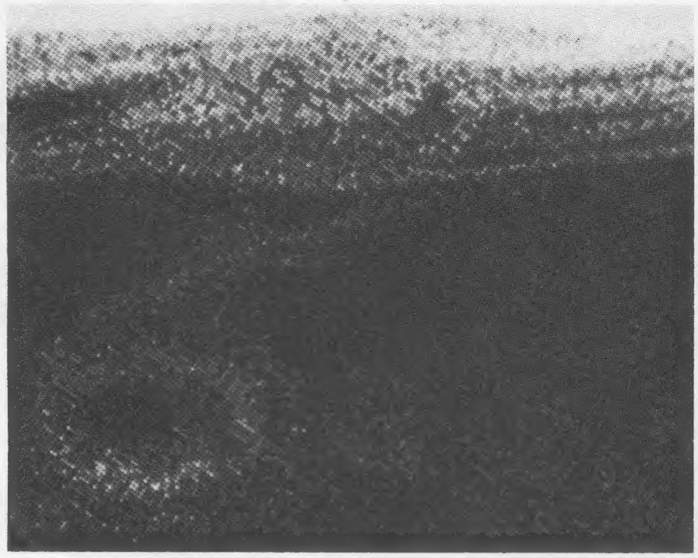
Mounting evidence indicates that Phoebe, Saturn's outermost satellite, is almost certainly a captured asteroid and did not form in the original Saturn nebula as did Saturn's other satellites. Voyager 2's observations of Phoebe on September 4 showed that it is about 200 kilometers (120 miles) in diameter – about twice as large as earth-based observations had measured it to be. It is darker than any other of Saturn's satellites, with about five percent reflectivity. The rotation period, determined from Voyager 2 observations, is nine to ten hours. Phoebe is the only Saturnian satellite that does not always show the same face to Saturn. It orbits Saturn (every 550 days) in the ecliptic plane rather than in Saturn's equatorial plane as do the other Saturnian satellites. Its orbit is also retrograde – in the direction opposite to that of the other satellites. 9/4/81 2.2 million km (1.35 million mi)

Color variations in Saturn's atmosphere are not as great as at Jupiter, probably due to differences in the mixing of chromophores which give color to gases. Indeed, from a distance, Saturn looks much like a butterball. However, upon closer inspection, and through different color filters, the real structure of the atmosphere becomes apparent. Saturn is banded, like Jupiter, but the bands cannot be so clearly defined as Jupiter's dark belts and light zones. In fact, Saturn's bands have little correlation with either wind velocities or temperature gradients. At Jupiter, the edges of belts and zones are generally high-speed jet streams flowing in opposing directions. Great wind shears lie between these jets. This apparently is not true at Saturn, where such high speed jet streams occur more often than

NASA
National Aeronautics and
Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Recorded Mission Status (213) 354-7237
Status Bulletin Editor (213) 354-4438
Public Information Office (213) 354-5011





A strangely curled cloud in Saturn's northern mid-latitudes gradually unfolded as Voyager 2 observed it. At left, it is "corkscrew"-shaped and at right, 64 hours later, it has become more like a "6". It is attached by a thin ribbon of cloud to the bright white cloud region to the north where winds blow 130 meters per second (290 miles per hour). Also evident is a ribbon-like structure at 47°N latitude in the white cloud region.
(L) 8/16/81 9.3 million km (5.8 million mi)
(R) 8/20/81 6.4 million km (4 million mi)

These pictures show the same region of the planet, but the frame on the right was taken through a violet filter and the one on the left through a green filter. The violet image shows a bright band about 3,000 km (1,900 mi) wide north of three bright oval cloud systems. Two of these storms lose contrast in the green image and are barely visible. The third and largest feature, 3,000 km (1,900 mi) in diameter, is dark in the green and has a measured clockwise rotation. 8/19/81 7.1 million km (4.4 million mi)

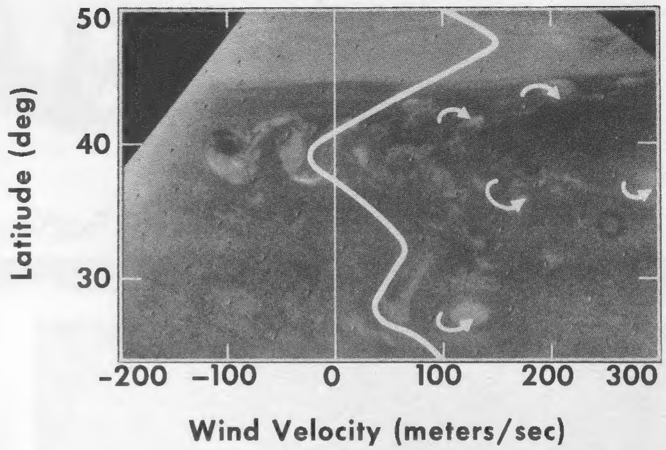
not in the middle of a band. (However, it is sometimes difficult to ascertain boundaries between Saturn's belts and zones since they appear differently depending on the color filter used to photograph them.) Between 35°N and 35°S latitude, Saturn's winds blow consistently eastward, with maximum speeds of at least 500 meters per second (1100 miles per hour) near the equator — four times the greatest winds on Jupiter. Few storm systems survive long due to the tremendous forces which drive these winds. Although Voyager 2 observed a gigantic storm system first seen by Voyager 1 last fall, storms such as Jupiter's centuries-old Great Red Spot and 40-year-old white ovals probably do not exist on Saturn.

The wind speeds are deduced from the time-lapse images taken by the spacecraft and are relative to the rotation rate of the bulk of Saturn's interior. This rate has been determined by the planetary radio astronomy experiment to be 10 hours 39 minutes 24 seconds.

Cloud vortices (small hurricanes), jet streams, and eddies are also evident at higher latitudes (up to 80°N) than at Jupiter (50°N and S). A train of vortices is apparent between 30° and 50°N.

For several days in late August, a large vortex in Saturn's northern mid-latitudes unfolded as Voyager 2 recorded its progress. Initially corkscrew-shaped, it became more like a "6" and eventually formed a closed loop over a period of seven rotations. Study of such events gives clues to the planet's atmospheric dynamics.

Twice as far from the Sun as is Jupiter, Saturn is much colder, with temperatures of 80 to 95 Kelvin at the cloudtops (where the atmospheric pressure is one-fourth Earth's). However, Saturn still radiates almost 2.5 times as much energy as it receives from the Sun. Eighty-nine percent of Saturn's atmospheric mass is hydrogen, while most of the remaining eleven percent is helium. This is much less helium that has been measured in Jupiter's atmosphere (19%), and lends credence to the theory that Saturn's helium sinks toward the center of the planet, providing a source of heat. Traces of ammonia, phosphine, methane, ethane, acetylene, methylacetylene, and propane have also been detected in Saturn's atmosphere.



A westward-flowing wind current appears to drive a wedge through a train of vortices (small hurricanes) at about 40°N latitude. The wind velocities are plotted on a photograph of this area and show the westward flow with obvious eastward streams above and below. As the vortice separates, smaller cyclones are formed. Those to the north rotate clockwise; those to the south rotate counterclockwise. This is one of the many interesting phenomena observed by Voyager 2.

The Rings

To say that Saturn's ring system is complex is a gross understatement. There are no smooth, well-defined, uniform rings marching around the planet in an orderly fashion, as once perceived. Voyager 1's images in November 1980 showed there to be hundreds of rings, some of them not quite well-behaved. Voyager 2's photopolarimetric observations upped that figure to literally thousands, and perhaps tens of thousands, of ringlets, few of them well-behaved or orderly.

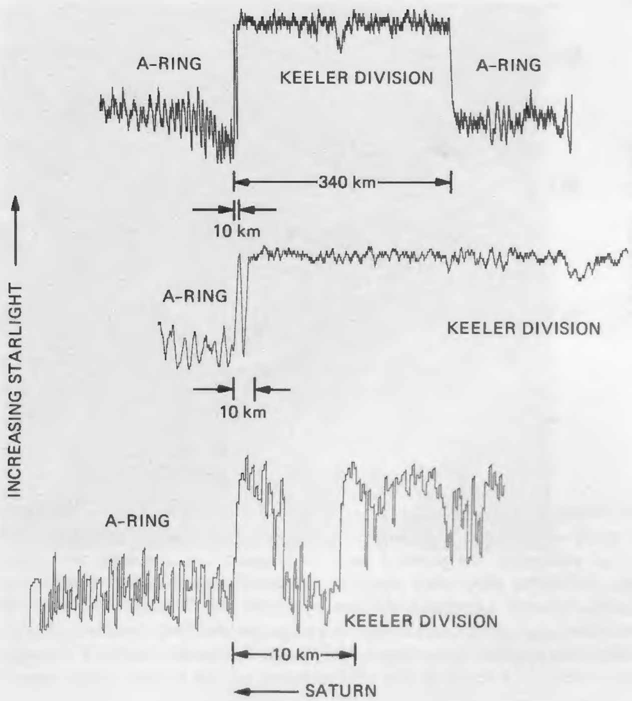
The main ring system extends from near the planet out to about 75,000 kilometers above the cloudtops, a vast sheet of icy debris varying in thickness, composition, and orbital characteristics. With resolution down to a city block – about 150 meters – the photopolarimeter's flood of data suddenly presents a new problem: what is a ring? what is the shoulder of one ring or the body of another? where does one ring end and another begin? It appears that some ringlets may narrow at the edges rather than having a uniform thickness (thus, they have so-called "shoulders"). Due to the viewing angles, none of Voyager's instruments determined with certainty the optical depth of a ringlet. Many of the ringlets are non-circular, indicating that structure changes rapidly, perhaps continuously, in the rings.

Several theories of the rings' stability have developed and were tested by Voyager 2's observations. Some mechanism is holding the ring particles in orbit around the planet; otherwise they would have escaped into space long ago. One theory supposes that the ring particles are in resonance with one of the larger satellites. Some of the larger "gaps" in the rings do indeed occur at distances corresponding to orbital resonances with Mimas (in a 2:1 resonance, the particles make two orbits for every one orbit by Mimas; Mimas also exerts a gravitational pull). A second theory proposes that small moonlets herd each ringlet. To test this theory, the imaging cameras searched the rings for evidence of such small moonlets, but none were found beyond those already known to shepherd the F-Ring. A third theory proposes density waves in the ring particles and some evidence of such waves is seen in Voyager data. A fourth theory involves collisions between the ring particles themselves. Relatively hard objects would ricochet off one another with some force, and would be less likely to stay in well-defined orbits. However, softer ice that has been banging around for billions of years will barely rebound, and in fact may shatter upon impact.

Voyager 2 re-verified the existence of the G- and D-Rings and photographed both of these plus the A, B, C, and F-Rings. The E-Ring was detected by the fields and particles instruments. Using the spacecraft's radio to determine particle sizes as the signal passed through the rings, analysts conclude the average particle sizes in the A-Ring are 10 meters (33 feet); in the outer Cassini Division 8 meters (26 feet); and in the C-Ring 2 meters (6.5 feet). Obviously, a "particle" can be anything from a dust speck to a very large boulder of ice.

Color differences within the major rings imply differences in composition, particle sizes, or both. Color-enhanced images of the C- and B-Ring show that some tiny ringlets within the C-Ring may have some compositional similarities to the B-Ring.

The mysterious finger-like structures in the B-Ring received a great deal of attention from Voyager 2, including some special ring plane crossing photographs and a series of time-lapse movies to study their formation and lifespans. These spokes form over very short time periods (minutes), primarily near the point where the ring particles emerge from Saturn's shadow. Most dissipate before completing a single orbit of the planet, but some remnants do persist and other spokes form on top of them. The spokes form radially; i.e., they extend outward from the planet like spokes in a wagon wheel, and they are seen on both faces of the rings, north and south (illuminated and unilluminated). (However, the features on the unlit side could possibly be shadows of spokes.) One theory proposes that the spokes are electrostatically-levitated particles of fine dust lifted above the plane of the rest of the B-Ring by Saturn's magnetic field lines which pass through the B-Ring in the spokes region. Three pictures were taken during ring plane crossing, when the rings could be viewed nearly edge-on, in hopes of seeing this phenomenon. The most spectacular of these pictures was 1/2 degree above the plane. No evidence of particle levitation could be seen from any of these pictures, however.

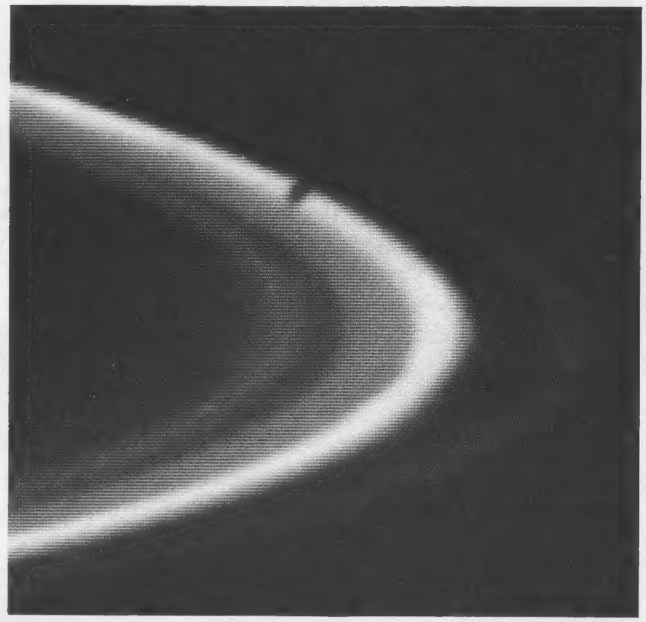


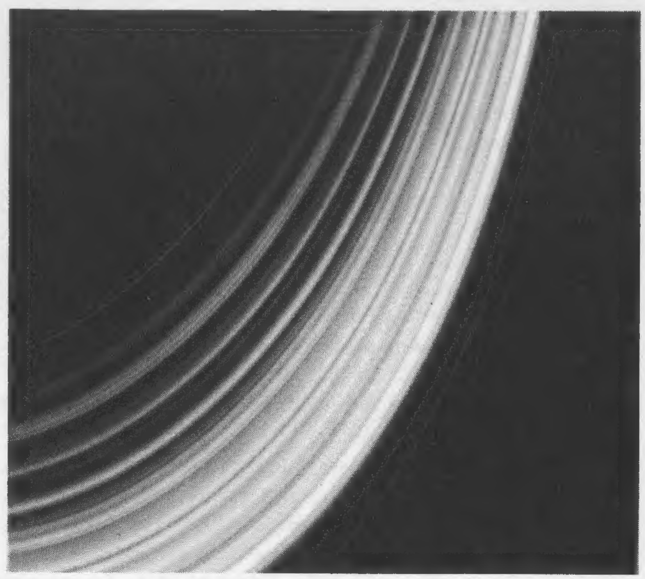
The high resolution of Voyager 2's photopolarimeter revealed ringlets that are undetectable by the cameras or radio system. These three plots show increasing resolution of an area including the Keeler (Encke) Division and the edges of the A-Ring. The amount of starlight (from the distant star Delta Scorpii) passing through the rings is plotted as a single line of varying brightness. Peaks in the curve indicate areas where there is little material to block the passage of starlight, while dips in the curve indicate areas where starlight is blocked by material. The Keeler Division is a relatively empty gap and therefore is seen as a peak in the top plot. The dip in the Keeler Division is probably the "kinky" ringlet photographed by Voyager 2's camera. With increasing resolution (moving down from the top plot), a feature at the inner boundary between the A-Ring and Keeler Division becomes apparent. This feature is believed to be a ringlet.

Voyager 1 detected lightning-like electrical discharges near the planet, with a periodicity of 10 hours 10 minutes, leading to speculation that these were occurring not in the planet's atmosphere but in the rings. During ring plane crossing, the plasma wave's radio receiver noted an enormous increase in the intensity of its signal, and the plasma wave investigators believe this indicates ionization of tiny dust particles hitting the spacecraft. The dust particles are not believed to have been sufficient to damage the spacecraft in any way, however.

The gap in the outer edge of the A-Ring known as the Encke Division may be renamed the Keeler Division in recognition of its probable discoverer. The Working Group on Planetary System Nomenclature of the International Astronomical Union (IAF) has been advised of the likelihood that James E. Keeler of Lick Observatory really saw this division in early 1888 (perhaps earlier) with a 90-cm refractor telescope. Until now, the discovery has been attributed to Johann Franz Encke, of the Berlin Observatory, who reported a shading in the A-Ring in 1837. It now seems unlikely that Encke, using a 22-cm telescope, could have seen a gap as small as this, and was seeing another feature. He reported a shading one-third the distance from the inner ring to the outer. In *The Astronomical Journal* (Vol. 8, page 175, 1889), Keeler reported seeing (with 400 power) the Encke shading on the outer A-Ring at about one-third its width from the outer edge. With a lens power of 1500, he reported seeing the inner shading and a division near the edge of the A-Ring about one-sixth the width of the ring from its outer edge. This is the location of the gap that has been known as the Encke Division. The issue will be discussed at the next IAU meeting.

At least four distinct components of Saturn's F-Ring are resolved in this edge-on image taken by Voyager 2's camera just prior to ring plane crossing. The camera resolution is about 10 km. The photopolarimeter, with a resolution of one city block, shows even more F-Ring components. Nearly 25 degrees of the ring are visible here. 8/26/81 103,000 km (64,000 mi)





As Voyager 2 passed over Saturn's rings, the photopolarimeter measured the intensity of light passing through the rings from the distant star Delta Scorpii and recorded the amount of starlight blocked or transmitted — an indication of the presence or absence of ring material. This picture of an area of the F-Ring was constructed with the aid of a computer graphics system by showing the recorded starlight intensity as a single line of varying brightness and then sweeping that line in an arc to achieve the two-dimensional effect. The perspective is from the Saturn side and slightly above the ring plane. Multiple "ministrands" can be seen in this area, which the imaging cameras recorded as the brightest strand in the F-Ring. From the inner to the outer ministrands, the distance here is approximately 70 kilometers (45 miles) and the resolution is 500 meters (550 yards).